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(54) Moving band filter

(57) An endless filter band extends between a lower filtrate-receiving shell 1 and an upper shell 2 which is vertically movable to clamp a section of the band between the shells during filtering, when a peripheral seal is maintained by feeding compressed gas into a space defined by a peripheral groove in shell 1 and a pair of sealing rings in the opposite face of shell 2 at a pressure P5 exceeding that inside the shells. The shells, band and supporting rolls are enclosed by an outer housing, lined with plastics and exhibiting external recesses which accommodate various mechanisms such as the rams which raise and lower shell 2 via sliding seals.

Magnetic markers on the band edges enable sensors to adjust a supporting roll to correct lateral deviations of the band during its moving periods between filtration. A scraper which removes cake for the band is automatically withdrawn as the markers or the join in the belt approaches, to avoid damage.

During filtering liquid is fed into shell 2 by gas pressure from a pre-filled chamber, and then more gas is fed to shell 2 until a maximum pressure is reached. Gas flow is then monitored to detect when gas breaks through the cake, whereupon the cake is washed in situ, pasing the same liquid repeatedly through the cake between a succession of reservoirs. The cake is finally dried by gas before raising a shell 2 and moving the band.

Filter aid may be used, by adding filter aid suspension to shell 2 without pressurising, before adding the liquid to be filtered under pressure, so that the filter aid layer is formed as formed as filtration begins.

Gas may be collected on the filtrate side and recycled to the upstream side of the filter.

cake dried

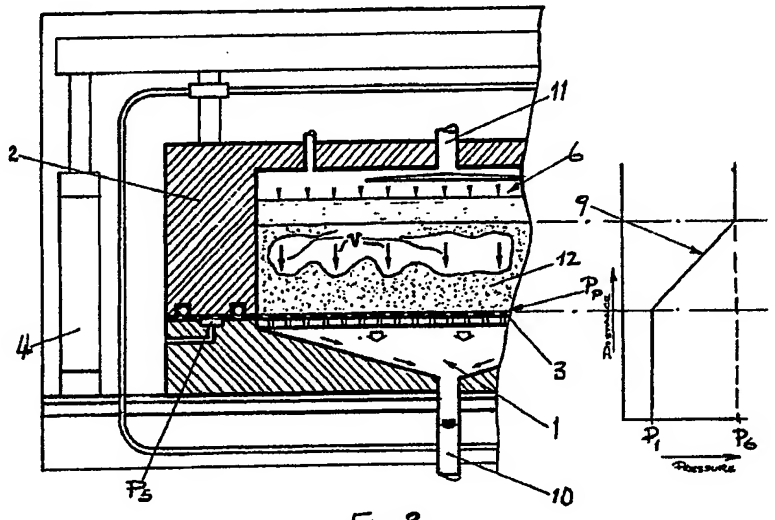

Fig 3

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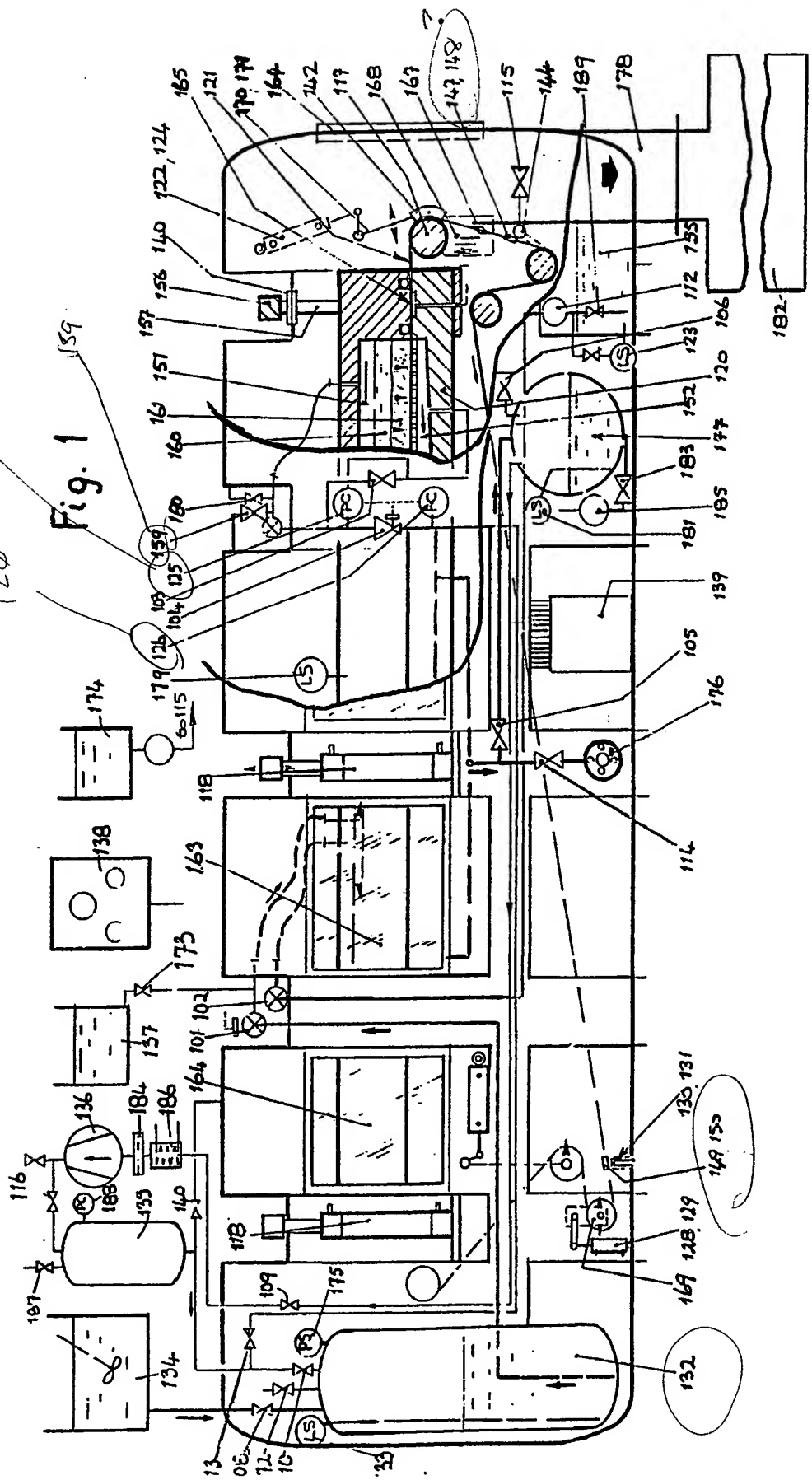
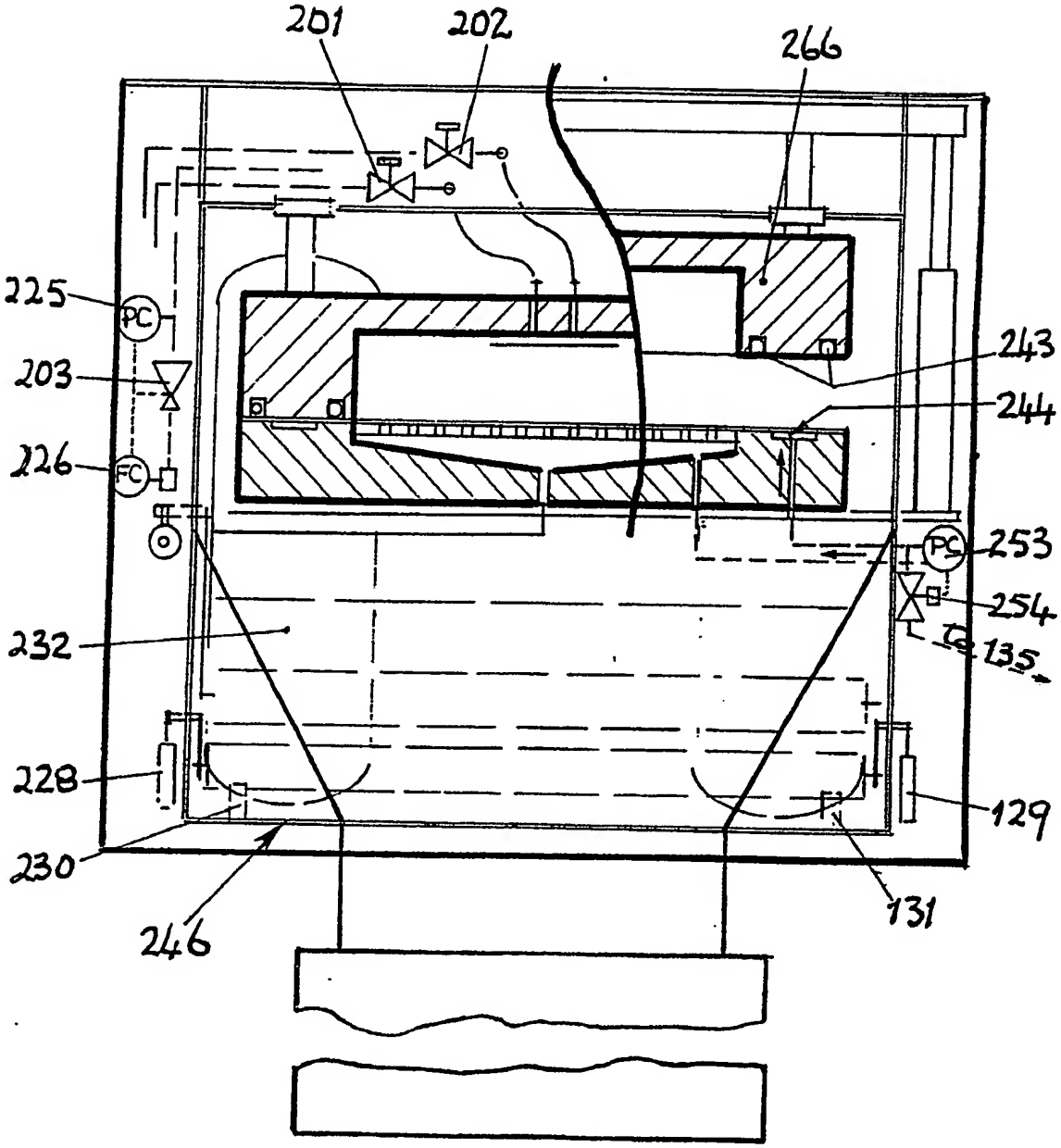


Fig. 1

Fig. 2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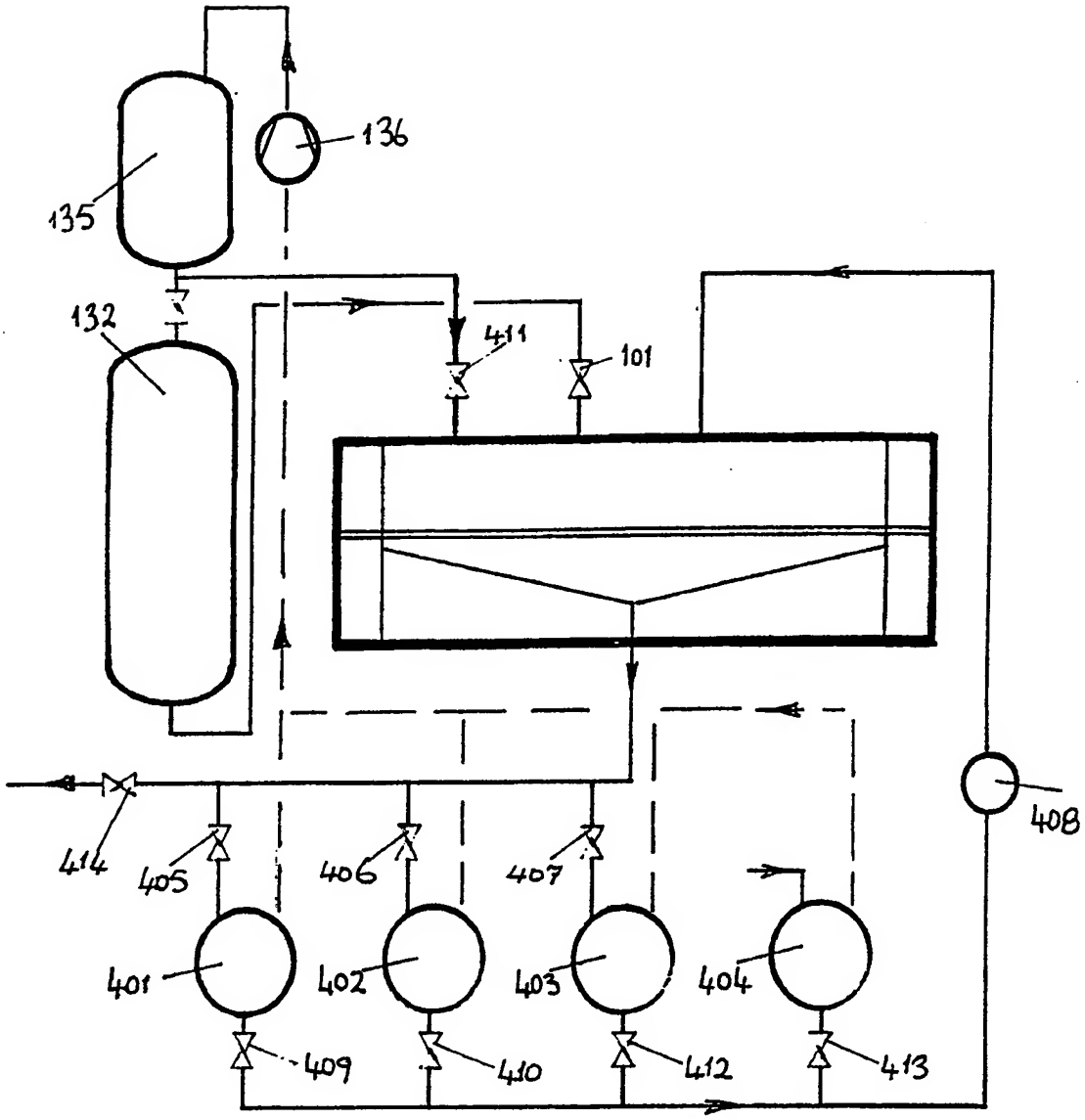
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Fig 4

Fig 5

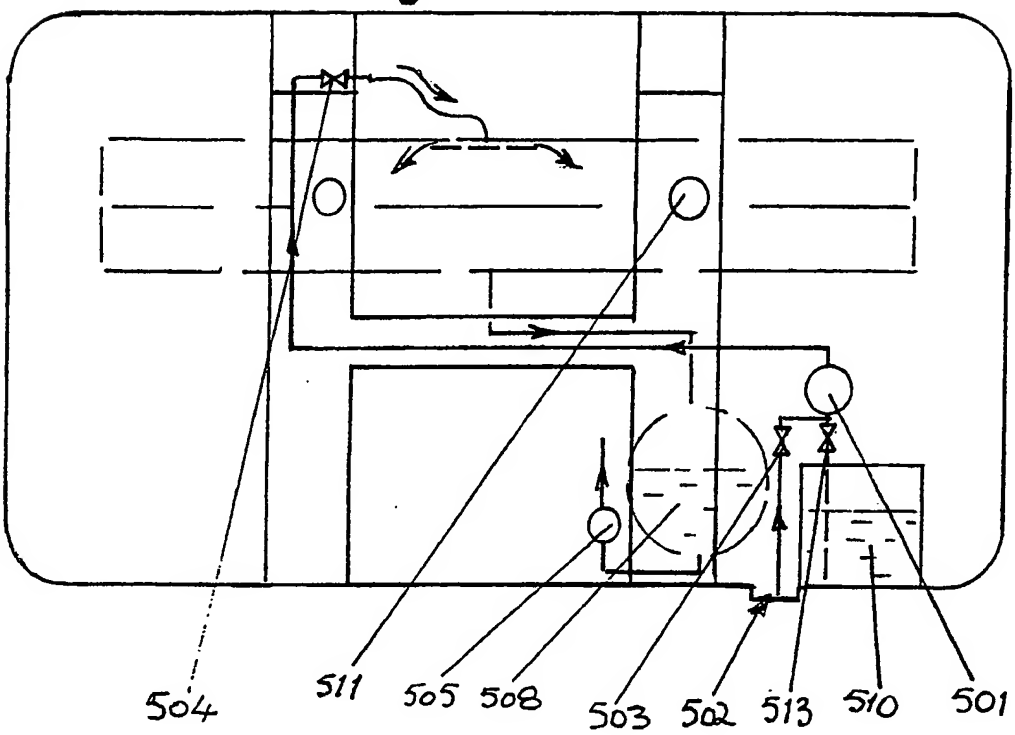


Fig 6

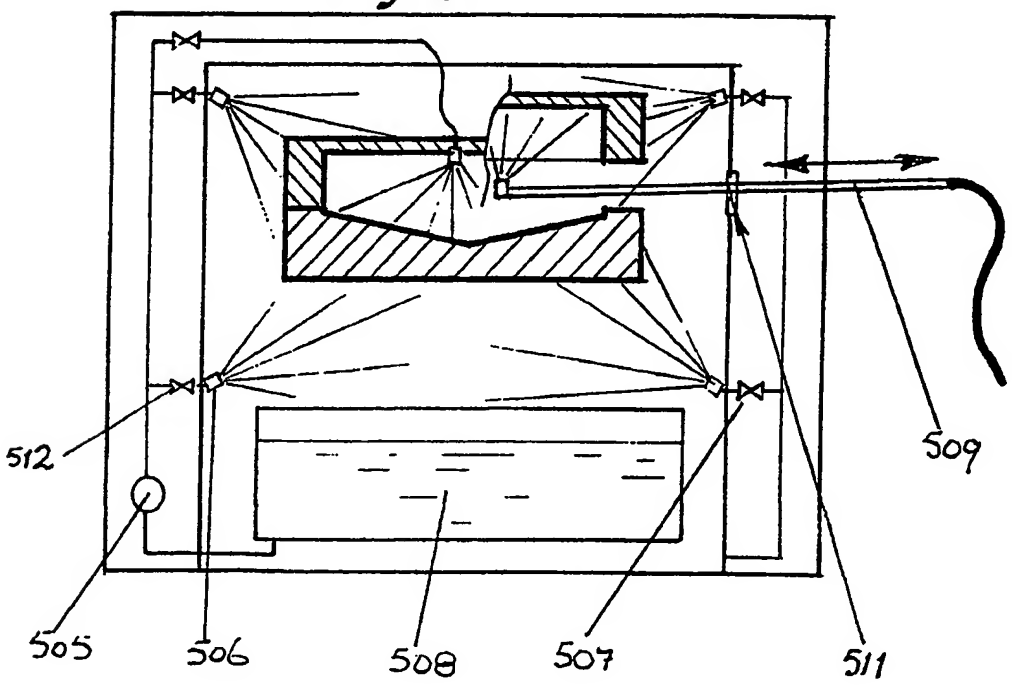
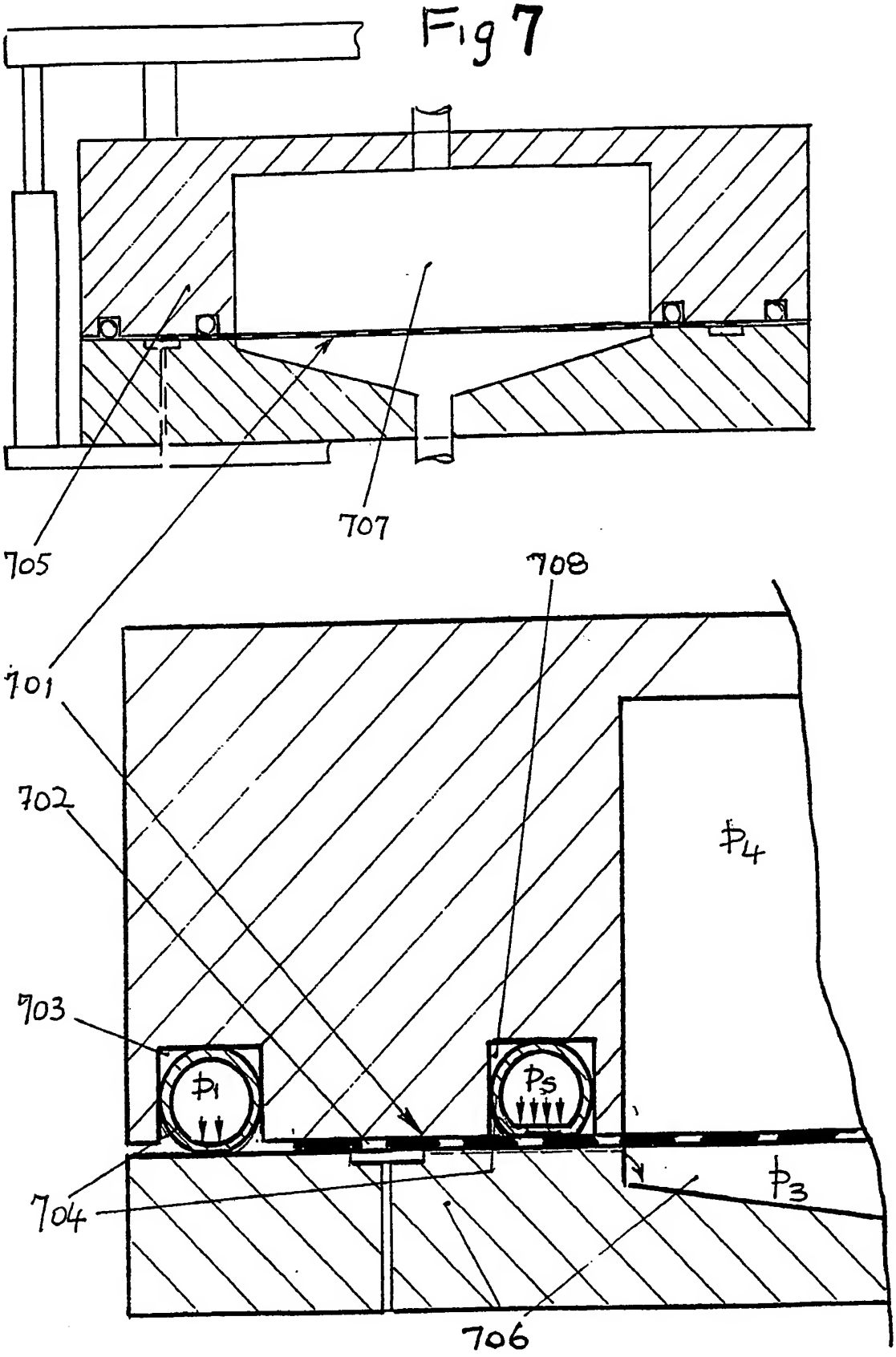


Fig 7



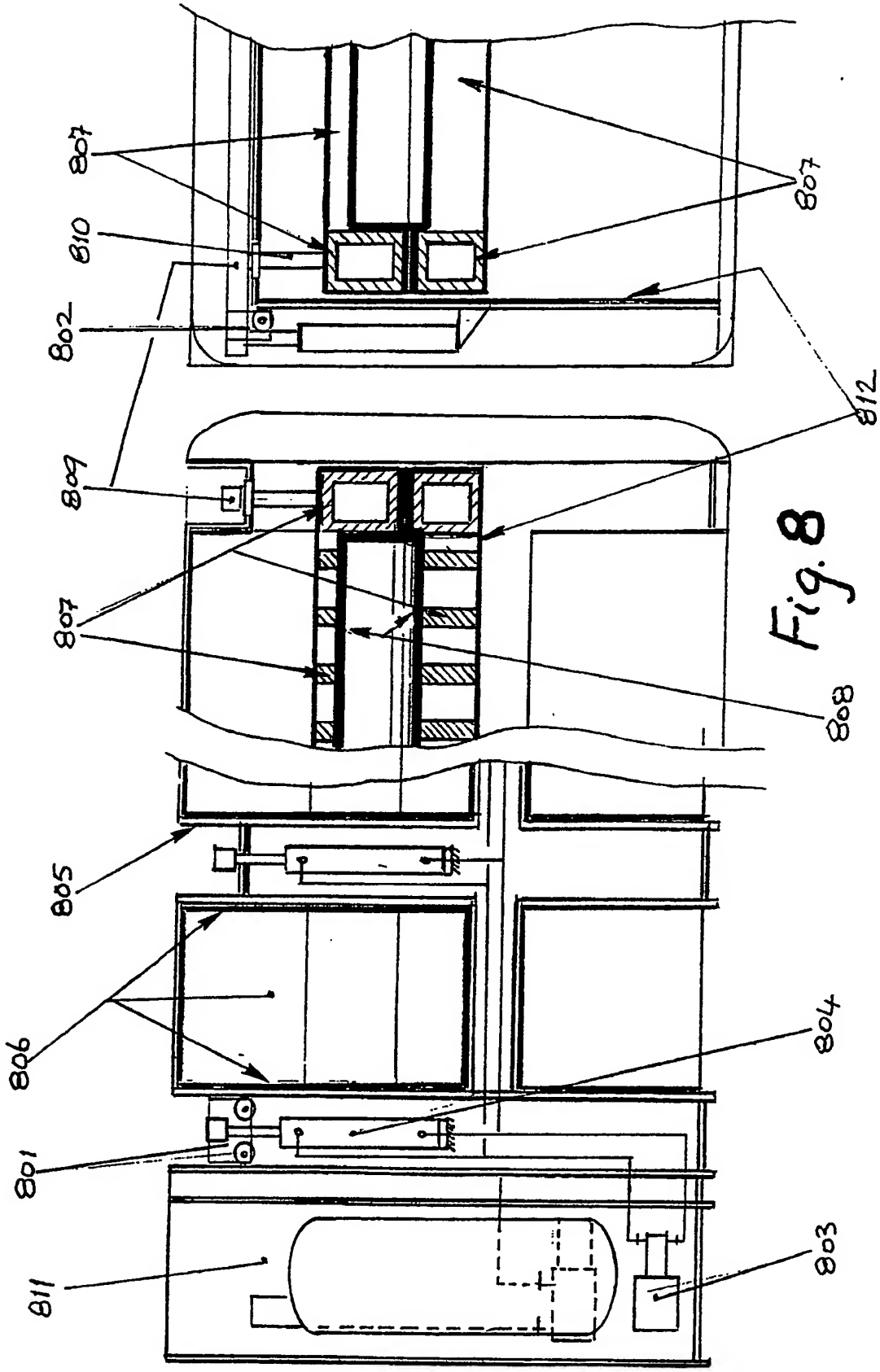


Fig. 8

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A BELT FILTER

This invention concerns a filter apparatus for liquids consisting essentially of a lower, horizontal filtrate chamber and an upper lid that is moveable in a vertical direction, the rim of which in the closed position seals a section of an intermittently moveable porous belt lying on and supported by the porous upper surface of the lower chamber, thus forming an upper chamber coinciding with the periphery of the lower filtrate chamber.

Background:

In an earlier stage of development as described in UK Patent Specification 1487401, a vacuum-suction pump connected to the lower filtrate chamber provided the sole source of differential pressure for the filtration operation, whereby the inherent chamber sealing problem associated with this type of filter was solved.

A further development as described in UK Patent Specification 2066094 replaced the disposable filter band of the earlier development with a filter band that could be regenerated and reused. This innovation resulted in the filter finding applications in the liquid processing industries such as the chemical, food and beverage producers.

Despite these successes it became evident that a general acceptance of this stage of development was being hindered by a combination of several remaining drawbacks:

1. The increasing demand for improved containment of the liquids and gases involved in the filtration operation could not be satisfied with the earlier designs. Simply enclosing the complete filter units in a gas-tight box only brought further and perhaps more serious problems

associated with lack of accessability and contamination of the interior and product due to leaks and corrosion from the ancillary equipment such as hydraulic actuators, bearings, etc.

2. The chamber sealing advantages of operating with vacuum pumps were offset by the disadvantage of being restricted to a maximum pressure difference of 1 bar and the increasing complexity of the vacuum system itself when handling solvents and corrosive liquids. The need for simpler operating systems with pressure differences in excess of 5 bar became apparent.

3. Filter band systems based on a gradual consumption of the medium according to the degree of blockage of the pores of the medium proved to be unacceptable in industries where valubale products such as pharmaceuticals and chemicals were being processed. The need presented itself for a more permanent filter medium in the form of an endless band or belt.

4. The earlier designs lacked an effective control over the course of the filtration operation. It proved to be difficult to control the rate of filtration by means of the control of the filtration pressure difference and the means for measuring the instantaneous rate of filtration was failing. To satisfy the increasing demands of the liquid processing industries the exact monitoring of the critical variables of the filtration process as well as the main mechanical aspects is necessary.

5. In the areas of application such as the pharmaceutical, chemical, food and beverage industries, a high degree of cleanliness and sterility of the interior and exterior parts of such filters is becoming increasingly demanded. The existing open, encumbered designs cannot fulfill these requirements.

The innovative design aspects that fulfill these requirements are depicted in the sectioned elevations Fig. 1 - 8.

A gas-tight shell 246 encloses the essential elements of the filter including the filter chambers and filter belt, which are made easily accessable by means of sealed windows such as 163, 164.

All fluid driven actuators and sensors, including the filter chamber rams 118, are located externally to the shell with the chamber-protruding thrust shafts 157 driven by transverse beams 156 through lip seals 140. The transverse beams are located in recesses in the top of the shell and are attached laterally to the thrust shaft of the rams that are contained in flanged recesses on the shell, thus allowing the whole chamber actuation mechanism to be sealed off from the shell internals and the surrounding environment. Additionally, all belt tracking and control means including rams, sensors, valves, drives, bearings, etc. are located externally to the shell 246 in recesses for sealing from the environment as well as the interior of the shell.

The innovative chamber sealing method of the invention is based on the principle illustrated in Fig. 3. An upper lid 2, moveable in the vertical direction by ram 4, in the closed position seals a section of porous band 3 lying on top of the lower filtrate chamber 1. Suspension under pressure is introduced through nozzle 11 into the top chamber 6 forming a filter cake 12. In the dynamic situation, with filtrate flowing through nozzle 10, a pressure gradient 9 exists through the filter cake corresponding to a pressure difference $P_6 - P_1$ where P_6 is the pressure in the gas space of the top chamber and P_1 is the pressure in the filtrate chamber 1.

For effective sealing of the filter chambers the pressure in the sealing space P_5 must exceed the pressure immediately above the surface of the porous filter medium P_p

i.e. $$P_5 - P_1 > P_p - P_1$$

According to the invention, the sealing of the filter chambers 151, 152, when operating with overall pressure differences in excess of 5 bar, is secured by maintaining a minimal pressure difference between the peripheral chamber sealing space 165 and the filtrate chamber space 152 during the entire filtration operation. A preferred method for achieving this is to contain a pressurized groove 244 in the peripheral sealing surface of the lower filtrate chamber 120 by means of laterally situated elastomeric seals 243, typically of the "O"-ring type, located in grooves in the peripheral sealing surface of the upper filter lid 266 which in the lowered position seals the groove 244 with respect to the filter chambers 151, 152 and the external environment. A pressure difference controller 253 adjusts the pressure in the groove 244 by means of a control valve 254 that on the input side is connected to a source of constant gas pressure 135.

The innovative aspects of the filtration medium system employed by this invention are associated with the necessity of controlling the intermittent movement of the filtration medium in the form of a porous belt and the requirement for the exclusion of all sources of potential contamination in the mechanical elements directly in contact with the belt and located within

the enveloping shell 246.

Practical considerations normally dictate that the material of the filter belt consists of some form of woven or non-woven fabric. Because of the basic filter design, a length of band with the required width must be fitted to the filter leaving the two ends to be joined together "in situ". The joint itself is invariably of such a design and dimension that precludes the possibility of positioning it within the sealed filter chambers during the filtration operation. According to the invention, electro-magnetically sensitive markers, typically 149, 150 and 147,148, are located on both sides at selected positions along the length of the belt. Belt markers

Sheathed electronic sensors 130, 131 are shown, typically positioned, set into the floor of and protruding into the enveloping shell 246. These control both the lateral divergence of the filter belt when in motion (band tracking) by initiating the appropriate swiveling action of the roller 169 by means of the externally located rams 128, 129 and the length of travel of the belt by deenergising the belt drive motor 168.

The size and shape of the above mentioned belt joint and marker design cause severe obstruction to known forms of effective cake removal devices, including taut wires and close fitting belt scraper blades. The invention indicates that the solution to this problem is to fit the band scraping elements with pivoted arms 170, 171 which are moveable by means of externally located rams 122, 124. Here again, the belt sensors 130, 131, sometimes in combination with timers located in the control panel 138, can be used to initiate the activation of the rams 122 to ensure that the cake removal and band scraping elements are lifted from the belt to allow an unrestricted passage of the joint and markers.

The novel method of filtration control of the invention utilizes a pressure differential controller 125 and a gas flow controller 126 in combination, producing an output signal controlling the actuation of the gas throttling valve 104, situated in the gas conduit and the suspension feed control valve 101 leading into the top filter chamber 151. With this configuration, the instantaneous rate of filtration can be measured and controlled according to a constant pressure differential mode of operation and the monitoring and control of the gas flow into the top chamber at constant pressure can be utilized for signalling the end of the filtration and initiating the subsequent cake washing and cake drying operations.

Fig. 5, 6 illustrate the novel system for maintaining internal shell and filter chamber cleanliness and sterility.

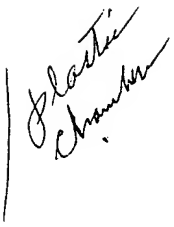
To reduce the size of the spray pump 505 and the volume of the wash liquid to economic and manageable proportions, sections of the shell internal and the filter chambers are washed consequtively with a reduced volume of the same charge of liquid. For maximum economy, Fig. 6 indicates the possibility of operating each spray nozzle separately and consequtively, whereby the used wash liquid is collected in the sump depicted in Fig. 5 at 502 from where it is transferred by the pump 501 through the valves 503, 504 into the top filter chamber and collected as filtrate in the receiver 508 for reuse with the suceeding wash operation.

Fig.8 shows views of the novel shell and filter chamber designs of the invention.
The structural strength of the shell is supplied mainly by the cage-like construction out of channel-shaped metal 805. This channel type construction provides the recesses for containing the fluid driven rams 804 that actuate the filter lid. The channels also house further ancillary equipment such as cylinders, conduit, valves, bearings, sensors etc. One preferred fluid actuation system for the filter lid consists of a standard hydraulic pump 803, located in a separately sealed ancillary equipment space 811 also housing such equipment as pressure vessels, gas compressors, heat exchangers, gas filters, etc. The hydraulic pump actuates multiple rams 804 located in the recesses provided by the channel cage-like structure that also acts as guides for wheeled carriages 801,802 preferably attached to the extremities of the transverse beams 809 actuating the filter lid through thrust shafts 810 and ensuring that the filter lid remains horizontal during both the raising and lowering movements.

Fig 8

The preferred method in the invention of sealing and enclosing the channel structure 805 to provide a gas-tight shell is by filling the gaps and lining the channels with weldable thermoplastic or corrosion resistant metal sheet material 806,812.
The preferred filter chamber design of the invention consists essentially of enclosing and encapsulating ribbed frameworks 807 out of a material such as mild steel with skins or linings 808 out of valuable, corrosion resistant materials such as nickel, hastelloy, titanium, etc. forming the internal surfaces of the filter chambers and the external skins 812 normally out of

less valuable materials such as thermoplastics and stainless steel. Instead out of metal, the internal chamber skins 808 can be fabricated out of thick plates of thermoplastic, such as polypropylene. In this way filter chambers with filtration areas of 10m², capable of withstanding internal pressures of 5 - 10 bar, can be fabricated with wetted surfaces out of the more expensive, exotic materials and thermoplastics for application in the pharmaceutical, chemical and food industries.



Description of Operation:

A widely practiced operation in the liquid/solid processing industries is the recovery of valuable solids by means of filtration. The solids are normally recovered in the form of a filter cake from which as much of the liquid as possible is removed. The original liquid in the filter cake, which mostly contains unwanted substances in solution, is often displaced or washed out by a clean liquid after the filtration operation proper. This operation is usually referred to as cake washing.

The rams 118, actuated by pressurized fluid, lower the filter lid 266 thus sealing a section of porous filter belt 121 lying on the bottom filtrate chamber. The signals for the actuation of the rams originate in the master control panel 138 and are received by the interface panel or junction box 139 located on the filter plant. All other actuators of the plant, such as valves, motors, etc. are controlled in the same way. These are known as input signals. Output signals from the plant originating from pressure switches, sensors, etc. also pass through the interface panel to the master control panel for processing as part of the filtration programme.

The control valve 254 opens and the pressure differential controller 253 adjusts the pressure in the groove 244 of the sealing surface. The control valve 254 is connected on the inlet side to the pressurized gas supply tank 135.

On opening valves 108, 172 a predetermined quantity of suspension to be filtered is metered into the pressure feed tank 132. The quantity is controlled by the level switch 133. The valves 108, 172 then close.

Filtration:
With valve 110 open, tank 132 is pressurized from the pressure gas storage tank 135 and on reaching a set pressure, the pressure switch 175 initiates the filter chamber charging sequence:
Valves 101, 159 and 114 open. The suspension in the feed tank 132 is transfered into the top filter chamber 151 and is distributed over the surface of the sealed section of the porous filter belt 121. With the collapse of pressure in the feed tank 132, the pressure switch 175 initiates the filtration operation proper:
The valves 101,110,159 close and valve 113 opens. The differential pressure controller 125 through the throttling valve 104 then controls the rate of increase of the differential pressure between the top and filtrate chamber over a predetermined range. When a maximum value (e.g. 5 bar) is attained, the gas flow controller 126 monitors the rate at which filtration takes place at a constant pressure within the top filter chamber. Filtrate thereby flows through the filtrate chamber 152 and out the flange 176 to a filtrate receiver not shown.

Filter Cake Washing:
A sudden increase in the rate of gas flow through the filter cake indicates that the level of suspension 160 in the top chamber has been lowered to the surface of the filter cake 161 and that the first break-through of gas into the filtrate chamber has occured. Further passage of gas through the filter cake often leads to the formation of shrinkage cracks throughout he filter cake. This condition often results in poor cake washing results.
A signal from the gas flow controller 126 starts up the liquid pump 112 and valves 102, 189 open. The contents

of tank 155, containing a small amount of solids from the cake washing operation, are pumped into the top filter chamber and distributed over the whole surface of the filter cake. On a signal from the liquid level switch 123, valve 102 closes and the pump 112 shuts down. The gas flow controller 126 continues to monitor the rate at which the wash liquid displaces the mother liquid in the filter cake and a sudden rise in the gas flow rate initiates the cake drying cycle.

Cake Drying:

The increasing gas flow through the filter cake displaces, entrains and removes the maximum amount of wash liquid from the filter cake. On a signal from a timer in the master control panel 138 the valves 113, 254 close and both chambers are vented by opening valves 159, 103. The fluid driven rams 118 open the filter chambers by lifting the filter lid 266.

Cake Removal:

The motor 168, driving the belt drive roller 117, is actuated and the filter cake 161 is transported from the filter chamber to be removed from the filter belt 121 by a filter cake cutter or scraper 142 pivoted at the forward side of the belt drive roller. Simultaneous to the actuation of the motor 168, valve 115 opens, allowing wash liquid from the storage tank 174 to be pumped under pressure through the nozzles 144 to clean the surface of the belt by removing any residual, adhering aolids. The level switch 123 closes valve 115 when a predetermined volume is collected in the receiver 155. Timers in conjuction with sensors 130, 131 actuate rams 122 to lift the filter cake cutter 142 from the filter belt to allow an unimpeded passage to the belt markers 147, 148 and 149, 150 as well as the belt joint assembly 167. The filter cake falls through the chute

178 to a sealed container 182. After travelling a predetermined length, the belt drive motor is deactivated and the rams 118 return the filter lid to the sealing position.

Instead of batchwise filtration, whereby a given quantity of suspension is transfered to the filter chambers for filtration, a continuous mode of operation can be employed:
Valves 101, 159, 110, 114 open. The suspension in the feed tank 132 is forced into and fills the top filter chamber. On a high level signal from the level switch 179, the vent valve 159 closes. The pressure differential controller 125 automatically adjusts the feed valve 101 to obtain a predetermined rate of increase in the pressure difference between the top filter chamber and the lower filtrate chamber. Filtrate flows out the filtrate outlet flange 176 to a filtrate receiver not shown. On reaching a maximum value of pressure difference in the filter chambers, valves 101, 110 close.
Valves 113, 104 open and the maximum pressure from the pressure gas storage tank 135 is applied to the gas space in the top filter chamber. The rate of filtration of the rest layer of suspension 160 is monitored by the gas flow controller 126 until a sudden rise in the rate of flow initiates the cake washing and cake drying sequences followed by the cake removel operation as previously described.

A further widely practiced operation in the liquid/ sodid processing industries is the recovery of valuable liquids by means of filtration. The solids in this case are often discarded after the filtration in the form of a filter cake from which as much as possible of the valuable liquid has been recovered by means of a cake washing operaiton.

For liquid recovery operations requiring a high quality filtrate, what has become known as "precoat filtration" is often practiced. In this process, a thin layer of filter aid, usually in powder form, is formed on the section of filter belt sealed within the filter chambers and acts as the filter medium.

Precoating:
A volume of slurry consisting of filtrate and filter aid powder is prepared and contained in the storage tank 137. With valves 173, 159, 103, 105, 106 open the slurry contents in 137 are fed into the top filter chamber and form a thin layer. Valves 159, 103 are closed and valves 113, 104 are opened. On reaching a set level of pressure (e.g. 0.5 bar) valves 113, 104 are closed and valves 110, 101 are opened, thus forcing the suspension to be filtered in the pressure feed tank 132 into the top filter chamber. The pressure differential controller 125 actuates the feed inlet control valve 101 to obtain a predetermined rate of increase of the pressure difference between the top and bottom filter chambers. On reaching a set value of pressure difference, the breather valve 180 opens and is closed again by the level switch 179 sensing high level of suspension in the top filter chamber. To maintain a high level of suspension in the top filter chamber this venting procedure is repeated at regular intevals during the filtration cycle. The initial filtrate containing traces of solids is collected in the receiver 177 and on a signal from the level switch 181 the flow is diverted

by shutting valve 105 and opening valve 114. The filtrate proper now flows through the filtrate outlet valve 114 to a main receiver not shown. The collected filtrate in the receiver 177, depending on the quality requirements, can be pumped forward or recycled to the filter aid slurry tank 137 by means of the pump 185.
On reaching a set maximum pressure difference between the top and filtrate chamber valves 110, 101 are closed and the operations rest filtration, cake washing, cake drying and cake removal are carried out as previously described.

Filtration operations requiring the exclusion of air (oxygen), where inert gas blanketing of the equipment internals is mandatory, are carried out as follows:

Equipment Purging:
With the filter chambers and valves 105, 106, 104 open, the internal of the filter shell 246 is purged with inert gas by opening valve 140 and the pressure feed tank is purged by opening 110, 172. After a set time or when the oxygen concentration in the internals is below a certain level all the valves are closed again.

Once Through Operation:
All the previously described operations can be carried out in an identical mode with the inert gas supplied from the pressure feed tank 132 and through valves 113, 104 eventually leaving the system through the filtrate outlet flange 176.

Sealed Gas Recycling System:

When dealing with volatile liquids, such as solvents, and to reduce the consumption of inert gas, a gas compressor 136 is employed to recirculate and recompress the gas used during the filtration operation. Gas is sucked to the pump inlet from the filtrate receiver 177 after passing through a heat exchanger 186 and an entrainment separator 184 with valves 109, 116 open.

A gas pressure controller 188 actuates an inert gas supply valve 187 on the pressure gas storage tank 135 to replenish any losses of gas from the system. All the previously described modes of operation can be carried out using the gas recycling system, whereby however the filtrate receiver 177 provides the sole filtrate collection vessel.

In many liquid/solid separation processes in industry the amount of liquid consumed for the cake washing in filtration operations can be crucial to the economic viability of the whole process. An example of this is the recovery of sugar from calcium carbonate residues in the sugar beet industry.

By operating with the filtrate collection system shown in Fig. 4, the benefits of counter-current cake washing with respect to the reduced volume of wash liquid consumed for a given degree of solute recovery from the filter cake are provided. The filter cake is subjected to "n" successive cake washing operations (in the case shown in Fig. 4 n = 4).

The vessel 404 contains a quantity of solute-free wash liquid and vessels 403, 402, 401 contain wash liquid with an increasing concentration of solute.

At the end of the filtration operation, the contents of tank 401 are transferred to the top filter chamber by opening the valve 409 and actuating the pump 408. With valves 411, 414 open, concentrated filtrate is delivered to a receiver not shown on Fig. 4.
The contents of vessel 402 are then transferred to the top filter chamber by opening valve 410 and actuating the pump 408. The filtrate is collected in vessel 401 by opening valves 411, 405.
This mode of operation is repeated for the vessels 403, 404 after which vessel 404 is replenished with fresh wash liquid for the next cycle. The operations can be sealed by connecting the vents of each vessel to the inlet of the gas compressor 136 leading to the compressed gas storage tank 135.
With changes in product and at intevals with continuous production, operating plant in the liquid processing industries must be subjected to thorough cleaning and sterilizing procedures.
Referring to Fig. 5, after a filtration operation, with the filtrate receiver 508 empty, the contents of the band wash liquid receiver 510 are transferred to the top filter chamber by means of the pump 501 with the valves 504, 513 open. This wash liquid is then filtered as previously described and collected as filtrate in the receiver 508.
Referring to Fig. 6, the batch of filtered band wash liquid is then fed to selected wash nozzles, typically 506, by activating the pump 505 and opening the valve 512. This used batch of wash liquid is collected at the base 502 of the shell and the above described procedure is repeated until the whole of the shell internal is cleaned.
Finally, as an extra precaution, a manually operated spray lance 509 can be introduced through special seals 511 to reach and clean any part of the shell interior.

CLAIMS

1. A filter apparatus for liquids consisting of a lower horizontal filtrate chamber and an upper lid moveable in the vertical direction, the rim of which in the closed position seals a peripheral section of an intermittently moveable piece of porous filter medium lying on and supported by the upper, horizontal, pervious surface of the lower filtrate chamber, thus forming an upper chamber that is designed to receive and hold a suspension of solids in liquid introduced from an external source under such pressure conditions that a pressure difference between the top and bottom chamber is formed, whereby the liquid is sealed in the chambers by means of a sealing space provided in the peripheral sealing surfaces of both chambers for which means are provided to adjust the pressure of fluid introduced to the space from an external source.

2. A filter apparatus for liquids consisting of a lower horizontal filtrate chamber and an upper lid moveable in the vertical direction, the rim of which in the closed position seals a peripheral section of an intermittently moveable piece of porous filter medium lying on and supported by the upper, horizontal, pervious surface of the lower filtrate chamber, thus forming an upper chamber that is designed to receive and hold a suspension of solids in liquid introduced from an external source under such pressure conditions

that a pressure difference between the top and bottom chambers is formed whereby the liquid is retained in both chambers by means of a sealing space in the peripheral sealing surfaces of both chambers formed between two or more rows of grooves or groove-like structures cut in or attached to and extending around the entire periphery of the sealing surfaces and containing rings of elastomeric profiled cord or tube pressed into the grooves by pressing the filter lid onto the bottom filtrate chamber.

3. A filter apparatus according to Claim 1, where the peripheral sealing space is formed by a groove in the peripheral sealing surface of the lower filtrate chamber for which means are provided to adjust the fluid pressure when the filter lid is pressed onto the lower filtrate chamber.

4. A filter apparatus according to Claim 3, where the fluid pressure controlling mechanism consists of a device for maintaining a pressure differential between the peripheral sealing space and the space in the filtrate chamber during the filtration.

5. A filter apparatus according to Claim 3, where the peripheral sealing space can be extended by including the space that can be formed when two or more grooves are cut in or two or more groove-like structures are attached to the peripheral sealing surfaces of the

filter chambers, located on either side of and parallel to the groove in the peripheral sealing surface of the lower filtrate chamber and in which rings of elastomeric profiled cord or tube are fitted ao that a portion protudes out of the plane of the sealing surface so that when the lid is pressed against the filtrate chamber the cord or tube is pressed into the groove flush with the top surface of the peripheral section of filter medium.

6. A filter apparatus for liquids consisting of a lower horizontal filtrate chamber and an upper lid moveable in the vertical direction, the rim of which in the closed position seals a peripheral section of an intermittently moveable piece of porous filter medium lying on and supported by the upper, horizontal, pervious surface of the lower filtrate chamber, thus forming an upper chamber that is designed to receive and hold a suspension of solids in liquid introduced from an external source, for which means are provided for measuring the pressure difference between the upper and lower filter chambers as the suspension enters the upper chamber and controlling the pressure difference by adjusting the opening of a suitable control valve through which the suspension passes. thereby controlling the rate at which filtrate passes into and out of the lower filtrate chamber.

7. A filter apparatus for liquids consisting of a lower horizontal filtrate chamber and an upper lid moveable in the vertical direction, the rim of which in the closed position seals a peripheral

section of an intermittently moveable piece of porous filter medium lying on and supported by the upper, horizontal, pervious surface of the lower filtrate chamber, thus forming an upper chamber that is designed to receive and hold a quantity of suspension of solids in liquid introduced from an external source which is then filtered by introducing gas at a suitable pressure into the upper chamber whereby means are provided to measure and control both the flow rate of the gas and the pressure difference between the upper and lower chambers during the filtration.

8. A filter apparatus for liquids according to Clause 7, where the source of the gas introduced into the upper chamber is preferably an external reservoir of compressed gas connected to the upper chamber by a conduit in which a gas flow meter and a pressure differential controller are located that control a gas throttling valve also located in the gas supply conduit between the upstream gas flow meter and the downstream pressure differential controller.

9. A filter apparatus for liquids consisting of a lower horizontal filtrate chamber and an upper lid moveable in the vertical direction, the rim of which in the closed position seals a section of porous filter belt lying on and supported by the upper, horizontal, pervious surface of the lower filtrate chamber, thus forming an upper chamber designed to receive and

filter a quantity of a suspension of solids in liquid, whereby after the filtration the filter lid is raised and the residue of solids separated from the suspension is removed from the filter chamber for which means are provided for causing the belt to move and for scraping or cutting the residue from the belt after leaving the chamber, whereby further means are provided for causing the residue scraper or cutter assembly to be removed from and returned to the surface of the belt when a predetermined section of or point on the belt is about to pass or has passed through the said scraper or cutter, as well as means for stopping the movement of the belt at a desired position.

10. A filter apparatus for liquids consisting of a lower horizontal filtrate chamber and an upper lid moveable in the vertical direction, the rim of which in the closed position seals a peripheral section of an intermittently moveable porous belt lying on and supported by the upper, horizontal, pervious surface of the lower filtrate chamber that is designed to receive and hold a suspension of solids in liquid introduced from an external source under such pressure conditions that a pressure difference between the upper and lower chamber is formed and filtration takes place, after which the lid is lifted and the belt is caused to move to transport the filter residue from the chamber, whereby markers fitted along the edges of both sides of the belt or the edges themselves cause stationary sensors also located on both sides of the belt to initiate the actuation of rams or the like causing a swiveling action on a free running belt roller to correct any lateral belt divergence.

11. A filter apparatus for liquids consisting of a lower horizontal filtrate chamber and an upper lid moveable in the vertical direction, the rim of which in the closed position seals a peripheral section of an intermittently moveable porous belt lying on and supported by the upper, horizontal, pervious surface of the lower filtrate chamber, thus forming an upper chamber that is designed to receive and hold a suspension of solids in liquid introduced from an external source under such pressure conditions that a pressure difference between the top and bottom chamber is formed and filtration takes place, after which to remove the filter residue on the filter belt, the filter lid is lifted, by means of two or more fluid actuated rams, the shafts of which are fixed directly or indirectly to the filter lid, whereby the motion of the shafts of the rams are coerced to move simultaneously and in accord by sliding or rolling elements, also fixed directly or indirectly to the shafts of the rams, that move in close fitting, stationary guides that prevent movement of the filter lid in a horizontal direction or a lopsided manner.

12. A filter apparatus for liquids consisting of a lower horizontal filtrate chamber and an upper lid moveable in the vertical direction, the rim of which in the closed position seals a peripheral section of an intermittently moveable porous belt lying on and supported by the upper, horizontal, pervious surface of the lower filtrate chamber, thus forming an upper chamber that is designed to receive and hold a suspension of solids in liquid introduced from an external source under such pressure conditions that

a pressure difference between the top and bottom chamber is formed and filtration takes place, after which the filter lid is lifted to remove the filter residue on the filter belt by means of two or more fluid actuated rams, characterized by a gas-tight shell enclosing the filter chambers and the filter belt assembly, consisting of a cage-like structure, preferably out of channel shaped metal sheet or plate providing the structural strength of the shell as well as recesses for containing ancillary equipment and conduits actuating and leading to the interior parts of the shell and the filter chambers, whereby the gaps or spaces between the channels are filled with suitable corrosion resistant materials, such as thermoplastic sheet, which can also line the interior surface of the channels, thus forming a continuous corrosion resistant internal shell surface.

13. A filter apparatus for liquids according to Claims 11,12, where vertical channel-shaped recesses forming a part of each side of the filter shell, provide the external containment and guides for the fluid actuated rams providing the vertical movement of the enclosed filter lid, where the actuating parts of each pair of rams, one ram on each side of the filter shell, are attached to the underside of a transverse beam located above and extending across the top of the filter lid, to which it is attached by means of one or more thrust shafts passing through seals located in the floor of one of the channels forming a part of the roof of the filter shell.

14. A method of liquid filtration employing a filter apparatus consisting of an upper chamber formed by pressing a lid on and sealing a section of porous filter medium lying on and supported by a horizontal lower filtrate chamber, whereby after a volume of a liquid containing filter aid powder in suspension has been introduced into the top chamber, with the pressure in both chambers equalized, the liquid to be filtered is caused to be introduced and distributed into the top filter chamber at a more elevated pressure, thus causing a simultaneous formation of a filter aid layer on the surface of the section of sealed filter medium and the onset of the filtration of the liquid to be filtered.

15. A method of liquid filtration according to Claim14, whereby after the completion of the filtration, when the pressure in the top chamber has reached a maximum value, the supply of liquid to be filtered is disconnected and a flow of gas at a constant pressure higher than that in the filtrate chamber is introduced to the top filter chamber, whereby the rate of flow is measured and a sudden increase in the value measured is used as a signal for the introduction of a volume of cake wash liquid also at a pressure higher than that existing in the filtrate chamber, after which gas is again introduced and the flow rate measured, whereby a sudden increase in the flow rate is used as a signal for ending the filtration operation.

16. A filter using methods according to Claims 14,15, wherein the external source of the suspension of solids in liquid to be filtered takes the form of a pressure vessel optionally fitted with a liquid level switch and connected to a source of pressurized gas to force a given volume of suspension into the the interior of the top filter chamber to carry out the filtration operation.

17. A filter apparatus according to Claim 16, wherein the source of pressurized gas takes the form of a pressure vessel containing a volume of the gas under pressure, which on the delivery side is connected to both the pressure vessel containing the suspension to be filtered and the internal of the top filter chamber and on the inlet side is connected to a source of the pressurized gas for replenishment.

18. A filter apparatus according to Claim 2, provided with a filtrate receiver facility that takes the form of two or more separate vessels, the outlets of which can be separately connected to the inlet of a liquid pump feeding into the top filter chamber and the inlets of which can be separately connected to the outlet of the filtrate chamber of the filter apparatus and can be also separately connected to the inlet of a gas compressor leading to a pressurized gas storage tank.

19. A filter apparatus and method employing this apparatus according to Claim 12, consisting of a means for pumping the ocntents of a receiver used for collecting the liquid from a filter band washing operation into the top filter chamber where this quantity of liquid is filtered and returned to another receiver, preferably a filtrate receiver, from where it is in turn pumped to a suitable spray nozzle or group of spray nozzles located at points preferably adjacent to sealed recesses in a gas-tight shell for the purpose of cleaning or sterilizing all parts and surfaces contained in the shell interior, whereby according to the degree of cleanliness or sterility required, the process of filtration and spraying of a given volume of liquid is repeated any chosen number of times.

20. A filter apparatus for liquids consisting of a lower horizontal filtrate chamber and an upper lid moveable in the vertical direction, the rim of which in the closed position seals a peripheral section of an intermittently moveable porous belt lying on and supported by the upper, horizontal, pervious surface of the lower filtrate chamber, thus forming an upper chamber that is designed to receive and hold a suspension of solids in liquid introduced from an external source under such pressure conditions that a pressure difference between the top and bottom chamber is formed and filtration takes place, after which the lid is lifted to remove the residue on the belt, where both the filter chambers and the belt assembly are enclosed by a gas-tight shell and the whole is characterized by the provision of a closed filtrate receiving vessel connected to the outlet of

the lower filtrate chamber and the inlet of a gas compressing machine by means of conduits, whereby the compressor recompresses any gas entering the filtrate receiver from the filtrate chamber and delivers said gas to a gas storage vessel from where it is metered back into the upper filter chamber at the desired pressure during the filtration operation and in so doing forms part of a closed gas recycling system.

Amendments to the claims have been filed as follows

1. A filter apparatus for liquids consisting of a lower horizontal filtrate chamber and an upper lid moveable in the vertical direction, the rim of which in the closed position seals a peripheral section of an intermittently moveable piece of porous filter medium lying on and supported by the upper, horizontal, pervious surface of the lower filtrate chamber, thus forming an upper chamber that is designed to receive and hold a suspension of solids in liquid introduced from an external source under such pressure conditions that a pressure difference between the top and bottom chamber is formed, whereby the liquid is sealed in the chambers by means of the conditions of fluid pressure that are maintained in the space or spaces that are delimitated between the sealing edge or surface of the said rim of the upper lid and the external, peripheral sealing surface of the lower filtrate chamber and the wall or walls of one or more vertically moveable barriers located in or attached to and extending around the entire periphery of one or both of the said sealing surfaces whereby the free extremity of the said barrier or barriers that protrudes into or onto the said space closely conforms with the contours of the surface contacted after the said upper filter lid is pressed into secure stable contact with the lower filter chamber.

2. A filter apparatus for liquids consisting of a lower horizontal filtrate chamber and an upper chamber formed by a fixed roof, vertically moveable side wall or walls and a lower floor consisting of a section of porous medium demarcated when the said walls are lowered onto the said section of porous filter medium lying on and supported by the upper horizontal, pervious surface of the said lower filtrate chamber, whereby the said upper chamber is designed to receive and hold a suspension of solids in liquid introduced from an external source under such pressure conditions that a pressure difference between the top and bottom chambers is formed and is prevented from escaping from the top chamber by means of the conditions of fluid pressure that are maintained in the space or spaces that are delimitated between the sealing lower edge or surface of the said walls of the upper chamber, the external, peripheral sealing surface of the lower filtrate chamber and the wall or walls of one or more vertically moveable barriers located in or attached to and extending around the entire periphery of one or both of the said sealing surfaces and where the free extremity of the said barrier or barriers that form the lateral extremity of the said space closely conforms with the contours of the surfaces contacted after the said walls have been lowered into secure mating contact with the lower filtrate chamber.

3. A filter apparatus for liquids according to Claims 1,2, consisting of a plurality or group of chamber units arranged in tiers separately or where the chambers are integrated, in that the tops of the roofs of the top chambers form the floors of the adjacent lower filtrate chambers.

4. A filter apparatus according to Claim 1, 2, 3, where the sealing space or spaces are provided with one or a plurality of connections to an external source of pressurised fluid, so that a constant pressure is established in the entire peripheral space or spaces.

5. A filter apparatus according to Claims 1, 2, 3, 4, where the means are provided to measure and control the pressure difference between the sealing space or spaces and the internal of the lower filtrate chamber during the entire filtration operation.

6. A filter apparatus for liquids consisting of a lower horizontal filtrate chamber and an upper lid moveable in the vertical direction, the rim of which in the closed position seals a peripheral section of an intermittently moveable piece of porous filter medium lying on and supported by the upper, horizontal, pervious surface of the lower filtrate chamber, thus forming an upper chamber that is designed to receive and hold a suspension of solids in liquid introduced from an external source, for which means are provided for measuring the pressure difference between the upper and lower filter chambers as the suspension enters the upper chamber and controlling the pressure difference by adjusting the opening of a suitable control valve through which the suspension passes. thereby controlling the rate at which filtrate passes into and out of the lower filtrate chamber.

7. A filter apparatus for liquids consisting of a lower horizontal filtrate chamber and an upper lid moveable in the vertical direction, the rim of which in the closed position seals a peripheral

section of an intermittently moveable piece of porous filter medium lying on and supported by the upper, horizontal, pervious surface of the lower filtrate chamber, thus forming an upper chamber that is designed to receive and hold a quantity of suspension of solids in liquid introduced from an external source which is then filtered by introducing gas at a suitable pressure into the upper chamber whereby means are provided to measure and control both the flow rate of the gas and the pressure difference between the upper and lower chambers during the filtration.

8. A filter apparatus for liquids according to Clause 7, where the source of the gas introduced into the upper chamber is preferably an external reservoir of compressed gas connected to the upper chamber by a conduit in which a gas flow meter and a pressure differential controller are located that control a gas throttling valve also located in the gas supply conduit between the upstream gas flow meter and the downstream pressure differential controller.

9. A filter apparatus for liquids consisting of a lower horizontal filtrate chamber and an upper lid moveable in the vertical direction, the rim of which in the closed position seals a section of porous filter belt lying on and supported by the upper, horizontal, pervious surface of the lower filtrate chamber, thus forming an upper chamber designed to receive and

filter a quantity of a suspension of solids in liquid, whereby after the filtration the filter lid is raised and the residue of solids separated from the suspension is removed from the filter chamber for which means are provided for causing the belt to move and for scraping or cutting the residue from the belt after leaving the chamber, whereby further means are provided for causing the residue scraper or cutter assembly to be removed from and returned to the surface of the belt when a predetermined section of or point on the belt is about to pass or has passed through the said scraper or cutter, as well as means for stopping the movement of the belt at a desired position.

10. A filter apparatus for liquids consisting of a lower horizontal filtrate chamber and an upper lid moveable in the vertical direction, the rim of which in the closed position seals a peripheral section of an intermittently moveable porous belt lying on and supported by the upper, horizontal, pervious surface of the lower filtrate chamber that is designed to receive and hold a suspension of solids in liquid introduced from an external source under such pressure conditions that a pressure difference between the upper and lower chamber is formed and filtration takes place, after which the lid is lifted and the belt is caused to move to transport the filter residue from the chamber, whereby markers fitted along the edges of both sides of the belt or the edges themselves cause stationary sensors also located on both sides of the belt to initiate the actuation of rams or the like causing a swiveling action on a free running belt roller to correct any lateral belt divergence.

11. A filter apparatus for liquids consisting of a lower horizontal filtrate chamber and an upper lid moveable in the vertical direction, the rim of which in the closed position seals a peripheral section of an intermittently moveable porous belt lying on and supported by the upper, horizontal, pervious surface of the lower filtrate chamber, thus forming an upper chamber that is designed to receive and hold a suspension of solids in liquid introduced from an external source under such pressure conditions that a pressure difference between the top and bottom chamber is formed and filtration takes place, after which to remove the filter residue on the filter belt, the filter lid is lifted, by means of two or more fluid actuated rams, the shafts of which are fixed directly or indirectly to the filter lid, whereby the motion of the shafts of the rams are coerced to move simultaneously and in accord by sliding or rolling elements, also fixed directly or indirectly to the shafts of the rams, that move in close fitting, stationary guides that prevent movement of the filter lid in a horizontal direction or a lopsided manner.

12. A filter apparatus for liquids consisting of a lower horizontal filtrate chamber and an upper lid moveable in the vertical direction, the rim of which in the closed position seals a peripheral section of an intermittently moveable porous belt lying on and supported by the upper, horizontal, pervious surface of the lower filtrate chamber, thus forming an upper chamber that is designed to receive and hold a suspension of solids in liquid introduced from an external source under such pressure conditions that

a pressure difference between the top and bottom chamber is formed and filtration takes place, after which the filter lid is lifted to remove the filter residue on the filter belt by means of two or more fluid actuated rams, characterized by a gas-tight shell enclosing the filter chambers and the filter belt assembly, consisting of a cage-like structure, preferably out of channel shaped metal sheet or plate providing the structural strength of the shell as well as recesses for containing ancillary equipment and conduits actuating and leading to the interior parts of the shell and the filter chambers, whereby the gaps or spaces between the channels are filled with suitable corrosion resistant materials, such as thermoplastic sheet, which can also line the interior surface of the channels, thus forming a continuous corrosion resistant internal shell surface.

13. A filter apparatus for liquids according to Claims 11,12, where vertical channel-shaped recesses forming a part of each side of the filter shell, provide the external containment and guides for the fluid actuated rams providing the vertical movement of the enclosed filter lid, where the actuating parts of each pair of rams, one ram on each side of the filter shell, are attached to the underside of a transverse beam located above and extending across the top of the filter lid, to which it is attached by means of one or more thrust shafts passing through seals located in the floor of one of the channels forming a part of the roof of the filter shell.

14. A method of liquid filtration employing a filter apparatus consisting of an upper chamber formed by pressing a lid on and sealing a section of porous filter medium lying on and supported by a horizontal lower filtrate chamber, whereby after a volume of a liquid containing filter aid powder in suspension has been introduced into the top chamber, with the pressure in both chambers equalized, the liquid to be filtered is caused to be introduced and distributed into the top filter chamber at a more elevated pressure, thus causing a simultaneous formation of a filter aid layer on the surface of the section of sealed filter medium and the onset of the filtration of the liquid to be filtered.

15. A method of liquid filtration according to Claim 14, whereby after the completion of the filtration, when the pressure in the top chamber has reached a maximum value, the supply of liquid to be filtered is disconnected and a flow of gas at a constant pressure higher than that in the filtrate chamber is introduced to the top filter chamber, whereby the rate of flow is measured and a sudden increase in the value measured is used as a signal for the introduction of a volume of cake wash liquid also at a pressure higher than that existing in the filtrate chamber, after which gas is again introduced and the flow rate measured, whereby a sudden increase in the flow rate is used as a signal for ending the filtration operation.

16. A filter using methods according to Claims 14,15, wherein the external source of the suspension of solids in liquid to be filtered takes the form of a pressure vessel optionally fitted with a liquid level switch and connected to a source of pressurized gas to force a given volume of suspension into the the interior of the top filter chamber to carry out the filtration operation.

17. A filter apparatus according to Claim 16, wherein the source of pressurized gas takes the form of a pressure vessel containing a volume of the gas under pressure, which on the delivery side is connected to both the pressure vessel containing the suspension to be filtered and the internal of the top filter chamber and on the inlet side is connected to a source of the pressurized gas for replenishment.

18. A filter apparatus according to CLAIMS 1,2,3, with a filtrate receiver facility that takes the form of two or more separate vessels, the outlets of which can be separately connected to the inlet of a liquid pump feeding into the top filter chamber and the inlets of which can be separately connected to the outlet of the filtrate chamber of the filter apparatus and can be also separately connected to the inlet of a gas compressor leading to a pressurized gas storage tank.

19. A filter apparatus and method employing this apparatus according to Claim 12, consisting of a means for pumping the ocntents of a receiver used for collecting the liquid from a filter band washing operation into the top filter chamber where this quantity of liquid is filtered and returned to another receiver, preferably a filtrate receiver, from where it is in turn pumped to a suitable spray nozzle or group of spray nozzles located at points preferably adjacent to sealed recesses in a gas-tight shell for the purpose of cleaning or sterilizing all parts and surfaces contained in the shell interior, whereby according to the degree of cleanliness or sterility required, the process of filtration and spraying of a given volume of liquid is repeated any chosen number of times.

20. A filter apparatus for liquids consisting of a lower horizontal filtrate chamber and an upper lid moveable in the vertical direction, the rim of which in the closed position seals a peripheral section of an intermittently moveable porous belt lying on and supported by the upper, horizontal, pervious surface of the lower filtrate chamber, thus forming an upper chamber that is designed to receive and hold a suspension of solids in liquid introduced from an external source under such pressure conditions that a pressure difference between the top and bottom chamber is formed and filtration takes place, after which the lid is lifted to remove the residue on the belt, where both the filter chambers and the belt assembly are enclosed by a gas-tight shell and the whole is characterized by the provision of a closed filtrate receiving vessel connected to the outlet of

the lower filtrate chamber and the inlet of a gas compressing machine by means of conduits, whereby the compressor recompresses any gas entering the filtrate receiver from the filtrate chamber and delivers said gas to a gas storage vessel from where it is metered back into the upper filter chamber at the desired pressure during the filtration operation and in so doing forms part of a closed gas recycling system.

21. Filter chambers according to Clauses 1,2,3, consisting of encapsulated frameworks of less costly materials such as mild steel, where the wetted surfaces or skins are fabricated out of more expensive corrosion resistant materials such as hastelloy, nickel, titanium, etc. or thicker plates of materials such as polypropylene and where the external surfaces or skins of the chambers are fabricated out of less expensive, less corrosion resistant materials such as stainless steels and theromplastic sheet and where the peripheral framework is acted upon at evenly spaced points by hydraulic or pneumatic rams above and below the chamber sealing surfaces.

Patents Act 1977 Examiner's report to the Comptroller under Section 17 -39 - (The Search report)	Application number GB 9323886.3
Relevant Technical Fields (i) UK Cl (Ed.M) B1D (DMGF, DMGB, DMLC, DMLD, DMNA, DMNG) (ii) Int Cl (Ed.5) B01D (29/09; 33/056)	Search Examiner R T HAINES Date of completion of Search 15 FEBRUARY 1994
Databases (see below) (i) UK Patent Office collections of GB, EP, WO and US patent specifications. (ii) ONLINE DATABASE: WPI	Documents considered relevant following a search in respect of Claims :- 1, 3-5

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Category	Identity of document and relevant passages		Relevant to claim(s)
A	GB 2015366 A	(AMSTED INDUSTRIES INC)	1
X	US 5059318	(BENESI) fluid seal groove issued 1990	1,3,4

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